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Design and implementation of a token-ring optic local area network interface module

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THESIS

DESIGN AND IMPLEMENTATION OF A
TOKEN-RING FIBER OPTIC LOCAL AREA NETWORK
INTERFACE MODULE

by

Mary L. Anderson

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Thesis Advisor: John P. Powers

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DESIGN AND IMPLEMENTATION OF A TOKEN-RING FIBER OPTIC LOCAL AREA NETWORK INTERFACE MODULE

by

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Submitted in partial fulfillment of the
requirements for the degree of

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September 1989

ABSTRACT

This thesis describes the design and implementation of a token-ring fiber optic local area network (LAN) interface module. The token-ring protocol implementing the IEEE 802.5 standard is reviewed. The initial LAN electrical signal operating at 4 Mbps is provided by a LAN adapter card based on the TMS380 chipset developed for twisted pair copper wire. This design features analog implementations of both the input electrical circuitry of the optical transmitter and output electrical circuitry of the optical receiver. Successful LAN communications over the fiber optic link are described.

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I. INTRODUCTION

A. GENERAL

During the past few years, token-passing ring interface techniques have risen as a viable technology for local area network (LAN) applications. Simultaneously, optical fiber has become the preferred transmission medium for use in long-haul communication systems. The present use of optical fiber within a local area network is limited predominately to networks with a bus topology and utilizing either Carrier Sense Multiple Access with Collision Detection (CSMA/CD) or token passing protocols [Ref. 1:p. 238]. Within token ring LANs, present use of fiber optic cable is limited to backbone applications which link individual LANs together while fiber-to-terminal equipment is rarely implemented. [Ref. 2:p. 74] A broadened use of fiber within token-ring LANs will be recognized upon final completion of the Fiber Distributed Data Interface (FDDI) standards. These standards describe a fiber optic token-ring LAN that operates at 100 Mbps and employs a redundant, counter-rotating, dual-ring topology. The FDDI standards draw heavily from the existing IEEE 802.5 standard for dual twisted-pair copper wire. [Ref. 2:p. 78] Reference 3, IEEE 802.5, is the accepted standard for the token-passing LAN, operating at 4 Mbps and employing a single ring topology. The FDDI standards deviate from the IEEE 802.5 standard only

when required by its higher data rate and the intrinsic differences between electrical and optical signals.

B. THESIS OBJECTIVES

The subject of this thesis is a hardware design of a fiber optic LAN interface module. The initial objective was to identify and model the electrical signal produced by the token-ring LAN. The next objective was to design and build a fiber optic link, and then to pass the modeled signal over the link and correctly recover the signal at the distant end. The final objective was to transparently insert the fiber optic link into the LAN. A transparent insertion is being defined here as conforming to the following criteria:

- o meet existing standards of Reference 3 developed for dual twisted-pair copper wire,
- o not adversely affect the software protocol, and
- o allow the LAN to communicate over the fiber optic link.

C. THESIS ORGANIZATION

Chapter II provides the necessary background to ensure a baseline knowledge of local area networks with special emphasis on token-ring access and implementation. Chapter III presents design specifications and thoroughly describes the existing network system components. Chapter IV deals with detailed design, construction, and operation of the hardware that was built. In addition, Chapter IV also presents the

design performance when implemented within the LAN, followed by conclusions and recommendations in Chapter V.

II. BACKGROUND

A. LANS AND THE ISO MODEL

Local area networks include data and computer communication elements that are geographically confined to being less than 10 kilometers apart and generally utilizing a shared transmission media. [Ref. 4:p. 6]

In relation to the Open System Interconnection (ISO) model, local area network standards and protocols are applied at the lowest two layers as depicted in Figure 1. The lowest layer, the physical layer, defines the actual electrical and mechanical connections. The next layer, the Data Link layer,

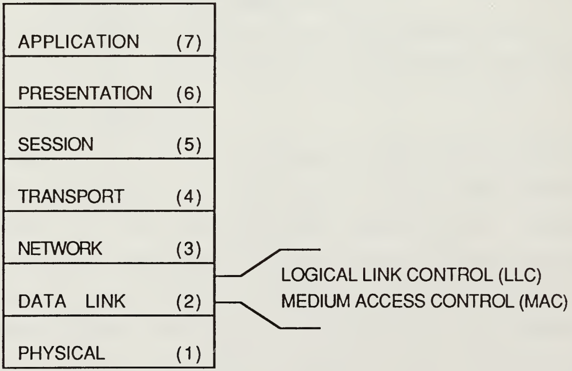


Figure 1. ISO Reference Model

is divided into the Medium Access Control (MAC) and Logical Link Control (LLC) sublayers. Together these sublayers define the way that data is formatted for transmission and how access to the network is controlled [Ref:5:p. 1-3]. There are several different MAC sublayers depending on the LAN topology and protocol. Some examples of MAC technology include:

- o star-wired ring topology using token passing access,
- o bus topology using CSMA/CD access, and
- o bus topology using token passing access.

B. TOKEN RING PROTOCOL

Although this research is confined predominately to the physical layer, a reasonable understanding of the MAC technology of the star-wired ring topology using token passing protocol is considered essential. Figure 2 illustrates the token access control mechanism. A token is an access-granting, unique symbol sequence that circulates from station to station on the ring.

In our system, the token is 3 bytes in length and consists of: a starting delimiter field (SDEL), an access control field (AC), and an ending delimiter field (EDEL). Each of these fields is 1 byte in length. The SDEL symbol sequence is JK0JK000. This pattern is used by the adapter for synchronization. (The J and K symbols are deliberate Manchester code violations that do not have a mid-bit transition. Manchester coding and these symbols are discussed

in more detail in Chapter III.) The AC field byte contains: the token indicator bit, 6 bits for priority indication and reservation, and the monitor count bit. The token indicator bit differentiates between a free token and a frame. The priority indication and reservation bits provides the mechanism within the token-ring protocol for prioritizing access on the ring. The priority levels are limited to 0 through 3 as are the reservation levels. The monitor count bit is used by the Active Monitor. An Active Monitor is the station on the ring that has the responsibility for ensuring normal ring operation. The Active Monitor receiving a 1 in the monitor count bit indicates a frame or reserved token was not properly removed from the ring. The Active Monitor then purges the ring and generates a free token.

The EDEL symbol sequence is JK1JK10X. Bit 7 of this sequence is an error detected indicator. This bit is 0 for no error and 1 for error detected. The EDEL, like the SDEL, is used by the adapter for synchronization.

The possessor of the token has exclusive use of the transmission media. The single token circulates on the ring, thereby giving each station on the net an opportunity to transmit data when it receives the token. Figure 2a depicts a free token circulating the ring. When a station has data to transmit, it captures the token and changes the token status to "busy". This is accomplished by changing the token indicator bit in the AC field of the token from 0 to 1.

(A one in the token indicator bit signifies a frame vice a free token.) The station then transmits a data frame.

The data frame format is strictly defined by the token-ring protocol and consists of the following fields listed in order of ring transmission:

- o Starting Delimiter field (SDEL),
- o Access Control field (AC),
- o Frame Control field (FC),
- o Destination Address (DA),
- o Source Address (SA),
- o Information field (data),
- o Frame Check Sequence field (FCS),
- o Ending Delimiter (EDEL), and
- o Frame Status field (FS).

The bit sequence of the SDEL, AC and EDEL fields in a data frame is identical to the respective fields of a token with the exception of the set token indicator bit as previously discussed.

The FC field is 1 byte in length and indicates the frame type as a MAC control frame or non-MAC control frame. MAC control frames execute the MAC layer protocol as discussed in Reference 3. This protocol implements a comprehensive set of problem determination, resolution, and reporting functions. Through the MAC frames, the ring communication problems are rapidly diagnosed and corrected. MAC frames originate from

and are processed by the station adapters. Therefore, the operation of MAC protocol is completely transparent to the individual host computers and provides a functionally reliable LAN.

Source and destination address fields are each 6 bytes in length. These fields identify the frame's originator and the frame's intended receiver.

The information field contains the data to be transmitted. The maximum length of this field is 4027 bytes.

The Frame Check sequence field contains a 32-bit cyclic redundancy code (CRC) that is used to protect the FC, DA, SA and information fields. The frame's source station provides the CRC that is used in the FSC field when the frame is transmitted. Each adapter calculates the CRC by a polynomial that is serially accumulated as the frame is transmitted or received. The received CRC in the FSC field is compared to the adapter's calculated value to verify that the frame was received without error.

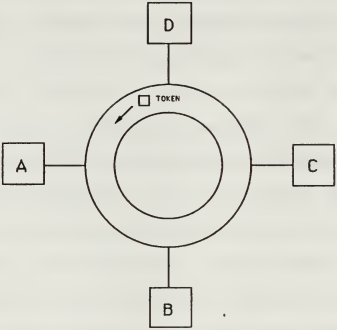
The frame status field is 1 byte in length. This field indicates to the frame source whether the frame destination address was recognized and if the frame was copied by the destination station.

Figure 2b depicts station A, after taking possession of the token, transmitting a data frame. Each station, when it is not the possessor of the token, functions as a repeater. A receiving station reads the frame and determines its

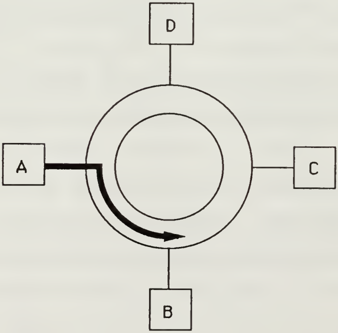
destination. If the frame destination is not the received station, the station repeats (retransmits) the frame. This repeater function is depicted in Figure 2c.

Figure 2d depicts station C as the frame's intended destination. The destination station copies the data and acknowledges receipt. This acknowledgement is accomplished by setting the frame copied (FC) indicator bits in the frame status field to 1. The destination station is also required to retransmit the frame. Once the data is received and acknowledged, it is the responsibility of the frame source station to remove its data from the ring and generate a new token. Figure 2e shows station A completing the transmission of the frame. Figure 2f depicts the originating station A removing its data from the ring and generating the new token. [Ref. 5:pp. 1-5 to 3-16]

Since all stations wait for the token to transmit data, and the station possessing the token has exclusive use of the transmission media, collisions (two or more stations attempting to transmit simultaneously) do not occur. This protocol, therefore, produces a reliable deterministic approach to LAN communications and eliminates the performance uncertainties of collision-based LAN protocols.

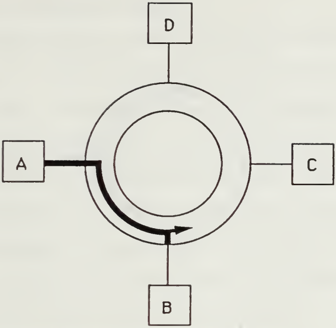


(a) Circulating token, any station can transmit upon receiving the token

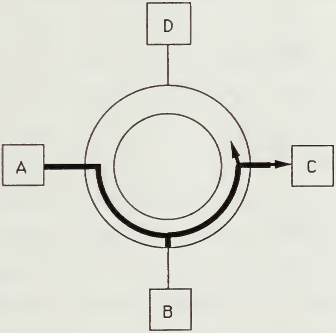


(b) Station A seizes token, transmits frame of data addressed to station C

Figure 2. Token Access Control for Message

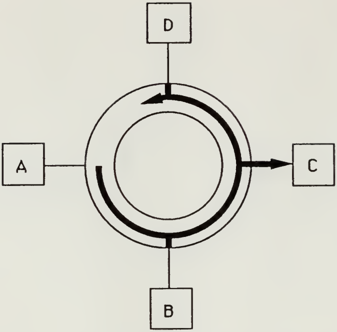


(c) Station B receives frame, checks address, and repeats frame

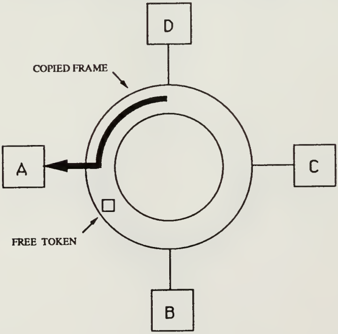


(d) Station C receives frame, recognizes address, acknowledges receipt and repeats data

Figure 2. (cont.)



(e) Station D repeats frame



(f) Station A receives acknowledgement and repeated data, transmits free token (only), the cycle repeats

Figure 2. (cont.)

C. TMS380 LAN ADAPTER CHIPSET

Texas Instruments and IBM jointly developed the integrated architecture of TMS380 chipset for connecting equipment to a token-ring LAN. Figure 3 is a block diagram of the TMS380 chipset consisting of five integrated circuit devices.

The TMS38030 system interface (SIF) chip provides the means to transfer data between the LAN adapter environment and the host system. The SIF asynchronously connects the host system bus, operating at data rates up to 5 Mbytes/sec, to the LAN adapter bus, operating at 6 Mbytes/sec. The SIF provides both direct memory access (DMA) and direct I/O (DIO) transfers between these buses.

A 16-bit high performance CPU with on-chip buffer RAM is contained on the TMS38010 communications processor. The dedicated CPU and RAM were designed to minimize the LAN adapter overhead burden on the host system by handling all the non-real time LAN functions. These functions include: controlling the operations of the SIF, preforming adapter bring-up diagnostics, executing the MAC protocol, managing the frame buffers with the on-chip RAM, and maintaining a working storage space also with the on-chip RAM.

The TMS38020 protocol handler performs the real-time hardware-based protocol functions compatible with the IEEE 802.5 standard. These functions include: differential Manchester encoding and decoding of data, recognizing frame addresses, and capturing free tokens. The protocol handler

also contains a on-chip ROM of 16K bytes of software used by the communication processor.

Jointly, the two chips TMS38051 and TMS38052 are the ring interface. Collectively, they connect the station to the LAN through separate transmit and receive channel pairs. In addition, they provide the phantom drive signal to physically insert the station into the ring. The phantom drive impresses a DC voltage on the transmit pair. (This DC voltage is transparent to the station's transmitted data, hence, the name "phantom".) The impressed DC voltage is used by the wiring concentrator to control relays that insert the station serially into the ring. Loss or absence of the phantom drive voltage results in the station being bypassed or removed from the ring. [Ref. 5:p. 1-8]

Use of a token ring LAN adapter card, based on this chipset, eliminates incompatibilities that could arise even at the chip level. This ensures interoperability and LAN connectivity within a token-ring network.

In summary, this chapter supplied a baseline knowledge of token-ring LANs. This baseline included: a review of the ISO model as it related to token-ring LANs, a discussion of the token-ring protocol, and a description of the TMS380 chipset. Chapter III presents the design requirements using these baseline concepts.

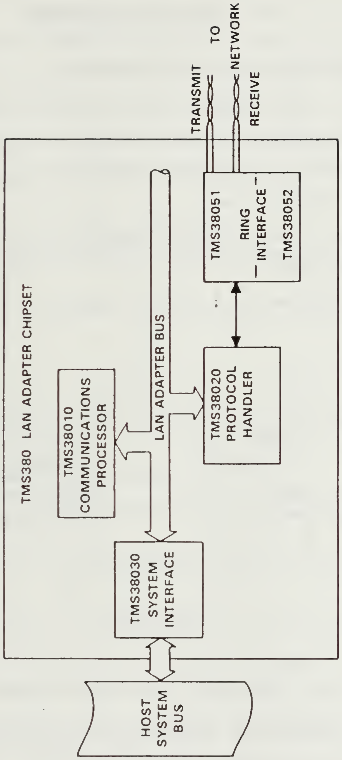


Figure 3. TMS380 LAN Adapter Chipset Block Diagram [from Ref. 5:p. 1-7]

III. DESIGN REQUIREMENTS

A. MICROCOMPUTER SYSTEM CONFIGURATION

Figure 4 is a block diagram showing the microcomputer system that provided the basic token ring LAN configuration for this thesis. This system consisted of:

- o two IBM XT clones,
- o a wiring concentrator (also referred to as a wiring hub, multiple access unit (MAU) or trunk coupling unit), and
- o two PC token-ring adapter cables.

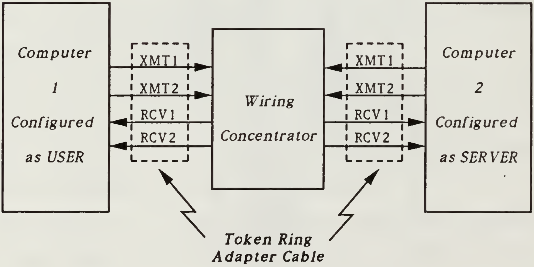


Figure 4. Local Area Network System Block Diagram

Each of the IBM XT clones had a token-ring LAN adapter card based on the TMS380 chipset installed. These cards are commercially available from NCR Corporation.

The wiring concentrator is a series of electrical switches which function to serially insert individual stations into the ring. The wiring concentrator is a passive device which is powered by the phantom drive of the ring interface which impresses a DC voltage on the transmit pair to cause the switching action. Figure 5 exemplifies the device insertion and bypass action of the wiring concentrator.

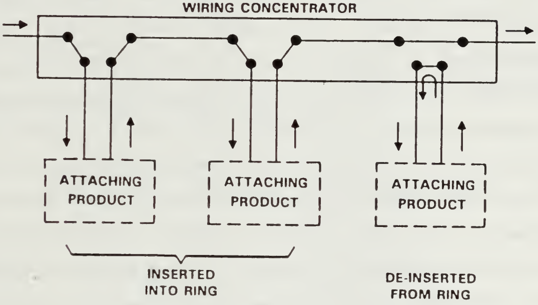


Figure 5. Token Ring Wiring Concentrator
[from Ref. 5:p. 1-4]

The LAN cables are terminated at one end with a male 9-pin subminiature "D" connector and terminated at the other end with a Medium Interface Connector (MIC). The "D" connector attaches to the installed LAN adapter card and the MIC attaches to the wiring concentrator.

The existing network software includes NCR Corporation versions of: PC Token-Ring System Installation, Token-Ring

Connection Adapter, NETBIOS, and PC Token-Ring LAN. When installed these four program packages provide all the necessary software (except DOS) for the operation of a token-ring LAN.

The PC Token-ring System Installation program is a menu-driven software package that prompts the user through the correct installation of the other LAN programs. The Token-Ring Connection Adapter program provides the LAN adapter software interface. This program package tests the LAN adapter board to insure that it is functioning properly and then enables the computer with an installed LAN adapter board to operate as part of a network. The NETBIOS (Network Basic Input/Output System) is a network software interface that runs on top of the adapter software interface to link LAN adapter software to the host computer. The PC Token-Ring LAN is a menu-driven application program that runs on top of NETBIOS. This application program allows network users the ability to perform variety of computer activities including: sending and receiving messages, using network disks and directories, utilizing network printers, and displaying the network status. Installation and use of these programs are thoroughly explained in References 6 and 7.

B. DESCRIPTION OF SIGNAL TO BE MODELED

Interconnection of data processing equipment by way of a local area network configured in star-wired ring topology and

using a token-passing access method is described by Reference 3, the ANSI/IEEE 802.5 standard. This standard provided the baseline for the signal to be modeled.

The signal consists of the following four differential Manchester encoded symbols:

0 - binary zero
1 - binary one
J - non-data-J
K - non-data-K

Differential Manchester coding is characterized by two symbol elements per bit with a forced mid-bit transition. Figure 6 pictorially describes the differential Manchester coding used within a token ring LAN.

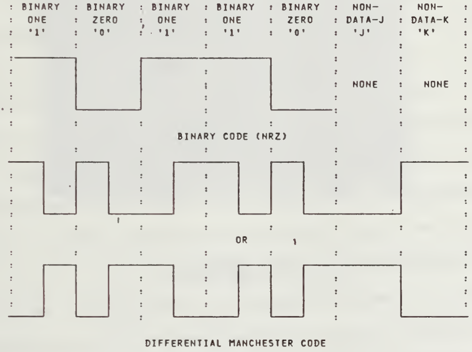


Figure 6. Example of Symbol Encoding
[from Ref. 3:p. 74]

The polarities of the line signal element sequence depends on the polarity of the trailing symbol element of the previously transmitted data or non-data bit. If a binary zero is to be transmitted, the leading symbol element is opposite of the trailing symbol element of the previous bit and there is a forced mid-bit transition. If a binary one is to be transmitted, the leading symbol element is the same as the trailing symbol element of the previous bit and there is also a forced mid-bit transition. The non-data symbol J has the same polarity as the trailing symbol element and there is no mid-bit transition. The non-data symbol K has the opposite polarity as the trailing symbol element and again there is no mid-bit transition. [Ref. 3:p. 73] The use of this encoding process transforms one bit into two baud (two symbol elements per bit). A two-baud structure allows the coding of the four symbols: binary one, binary zero, non-data J, and non-data K. The non-data J and K symbols are used within the token-ring protocol for frame format information and token boundary synchronization. [Ref. 5:p. 3-6] This is accomplished by the detection and exploitation of missing mid-bit transition within the non-data J and K symbols.

Figure 7 (taken at point (B) of Figure 8) is the signal to be modeled showing the data and non-data symbols. The wider sequence in the right-center of Figure 7 depicts the non-data J and K symbols. The surrounding narrower sequence in Figure 7 depicts the binary one and binary zero symbols.

The data signaling rate is 4 Mbps. Referring to Figure 8 at points (B) or (0), the transmitted signal is required to be between 3.0-4.5 volts peak-to-peak. The voltage changes between the 10% and 90% points of the output signal cannot exceed 25 ns. [Ref. 3:p. 80] The signal of Figure 7 conformed to these requirements and was measured at 4.4 volts peak-to-peak with transitions between the 10% and 90% voltage levels occurring in 22 ns.

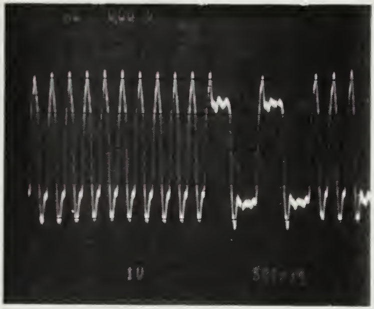


Figure 7. Oscilloscope Display of the Signal to be Modeled (4.4 volts peak-to-peak)

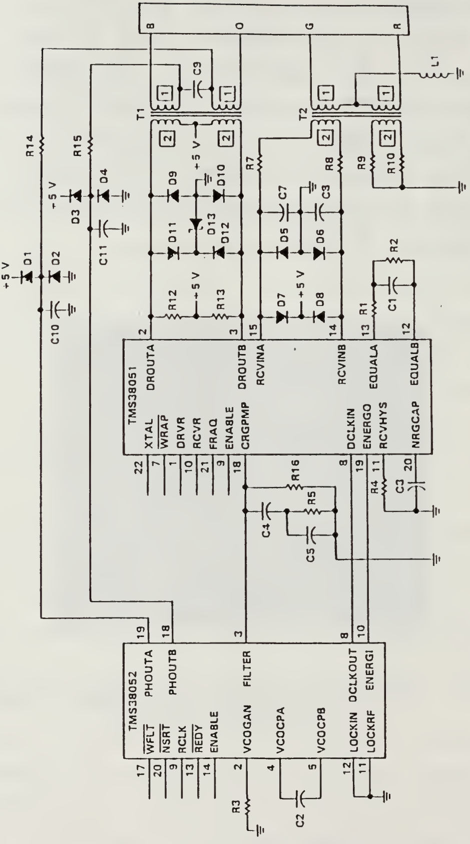


Figure 8. Schematic of Existing Output Interface Circuit [from Ref. 5:p. A-100]

IV. DESIGN DESCRIPTION AND EVALUATION

A. DESIGN APPROACH

With the required signal completely characterized, the choice of using analog or digital techniques to implement the design had to be made. The final design was decided by the available circuit components. The fiber optic receiver selection was the primary factor in the decision to employ analog methods. One available digital fiber optic receiver, HFBR-2402 by Hewlett Packard, is capable of supporting data rates up to 5 MBaud. [Ref. 8:p. 4-31] The LAN data rate of 4 Mbps using differential Manchester coding required 8 Mbaud of coded data, however. This exceeded the capabilities of the HFBR-2402, so we required the use of a different receiver. An available analog fiber optic receiver, HFBR-2404 by Hewlett Packard, was capable of supporting data rates up to 50 Mbaud with the appropriate output circuitry and more than adequately met the data rate requirement. [Ref. 8:p. 4-33] This resulted in the decision to use analog data transmission in the fiber optic link.

The HFBR-2404 receiver has a maximum receive signal pin voltage of 1 volt. This produced the requirement to amplify the electrical output from the optical receiver to the signal voltage of 3.0-4.5 volts (peak-to-peak) that the LAN requires. The selection of an operational amplifier to preform this

amplification was based on the need for a fast settling time and a wide bandwidth. As mentioned earlier, the LAN signal is required to transit between the 10% and 90% voltage levels in less than 25 ns; this was the driving specification in the op-amp finally chosen. The EL2020C by Elantec has 1% settling time of 50 ns but transits between the 10% and 90% voltage levels typically within 25 ns. [Ref. 9:pp. 80-82]

B. THE TRANSMITTER CIRCUIT DESIGN

The transmitter design is built around a direct intensity modulation scheme. In this scheme the transmitted signal is used to directly modulate the light source intensity. To accomplish this, a DC bias voltage is applied to the LAN signal, converting it from a bipolar signal (having both positive and negative polarities) to a unipolar signal (having only a positive polarity). This conversion is required due to the unipolar nature of light (i.e., light can have varying intensities but only a single polarity). The response time of the light source and the time constant of the circuit that provides the drive current determine the maximum rate for direct intensity modulation.

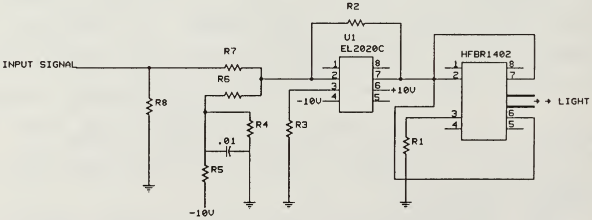
The complete transmitter circuit design is shown in Figure 9 with component values given in Table 1. The optical transmitter utilized was the HFBR-1402 by Hewlett Packard. This transmitter is an LED device, utilized for both analog and digital designs. The wiring of the HFBR-1402 (Figure 9)

is directly from Reference 8 with the exact value of R1 experimentally determined. As the value of R1 increases, the current through the transmitter LED decreases, thereby reducing the optical output power. If this resistor is too large, it causes the transmitter LED to operate near cut-off resulting in a distorted output signal. However, if this resistor is too small, it causes the optical receiver to saturate, resulting in a clipped signal. The required value of R1 was experimentally determined to be 15Ω. This value resulted in an undistorted signal being obtained by the optical receiver.

The transmitter circuit performs the two basic functions of providing a biased signal to the optical transmitter and providing impedance matching to the signal source. The voltage divider network of R4 and R5 is used to supply a pre-bias drive current to the optical transmitter to obtain a faster response time from the LED. The EL2020C is used in the inverting mode as a voltage summer. One input of the summer is the -3 volts supplied by the voltage divider while the other input is the LAN signal of approximately ± 2 volts (i.e., 4 volts peak-to-peak). The output of the summer is the biased signal used to directly intensity modulate the optical transmitter.

The impedance-matching to the LAN signal source is provided by R8. The value of R8 was experimentally determined to be 2KΩ. During the initial testing of this design using

a signal generator to produce the model of the LAN signal, the need for this impedance matching resistor was not apparent. When the final fiber link was inserted into the LAN, however, the value of this resistor determined whether or not the LAN functioned properly. When this resistor is too small, an adapter hardware error message from the Token-Ring connection Adapter program is received and access to the network is denied. However, when this resistor is too large, access to the network menu is granted but communications between the two computers is not achieved. Although the exact cause of this inability to communicate is not known, it is theorized that the impedance mismatch interferes with the ring polling process. This process enables the computer to acquire the specific address of its upstream neighbor. Since these computers are the upstream neighbors of each other, without an upstream neighbor address they do not recognize each other as network stations and, therefore, cannot communicate.



NOTE 1: All op-amp power supplies are capacitively coupled to ground by 4.7uF tantalum capacitors.
NOTE 2: All capacitor values are in microfarads.

Figure 9. Transmitter Circuit Schematic

TABLE 1
OPTICAL TRANSMITTER CIRCUIT COMPONENT VALUES

R1 = 15	R5 = 1K
R2 = 1K	R6 = 1K
R3 = 330	R7 = 1K
R4 = 430	R8 = 2K

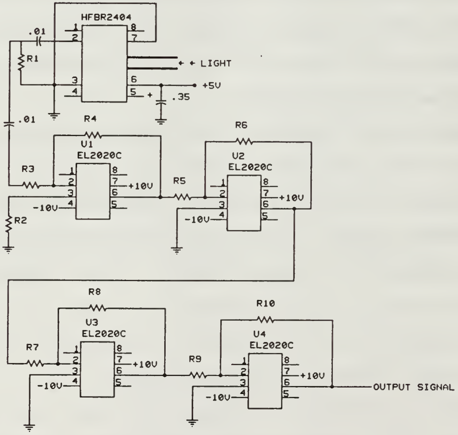
C. THE RECEIVER CIRCUIT DESIGN

The receiver design (Figure 10) accepts the incoming modulated light signal, converts it to an electrical signal, and amplifies the electrical signal through a series of stages to recreate the LAN signal.

The complete receiver circuit design is shown in Figure 10 with component values given in Table 2. As stated previously, the optical receiver utilized was the HFBR-2404 by Hewlett Packard. This receiver contains a PIN photo-diode and produces an inverted analog voltage replica of the received optical signal. Although the actual internal wiring of the HFBR-2404 is not explicitly supplied in Reference 8, connecting the device is straightforward.

The amplification stages of the receiver were mathematically determined and experimentally optimized. The gain was accomplished in stages to maintain a wide bandwidth. Not doing so would result in severe signal distortion. For a given gain, the bandwidth can be increased by decreasing the feedback resistor, but reducing the feedback resistor results

in excessive overshoot, ringing, and (eventually) oscillations. Four stages were experimentally determined to balance this gain/bandwidth tradeoff. The gain of each stage, listed in order from the detector, are: inverting gain of 2, inverting gain of 10, inverting gain of 1.5, and inverting gain of 1. The last stage corrects the polarity of the output signal to match the original signal from the transmitter.



NOTE 1: All op-amp power supplies are capacitively coupled to ground by 4.7uF tantalum capacitors.
NOTE 2: All capacitor values are in microfarads.

Figure 10. Receiver Circuit Schematic

TABLE 2
RECEIVER CIRCUIT COMPONENT VALUES OPTICAL

R1 = 510	R6 = 1K
R2 = 330	R7 = 430
R3 = 330	R8 = 680
R4 = 680	R9 = 750
R5 = 100	R10 = 750

D. DESIGN EVALUATION

The design evaluation started with the requirement to pass the modeled LAN signal over the fiber optic link and correctly recover the signal at the distant end. The LAN signal was modeled as a square wave with frequencies varying from 1 to 4 MHz using a signal generator. These signals were applied to the optical transmitter circuit of Figure 9 and measured at the output of the receiver circuit of Figure 10. The varying frequencies account for the dissimilar number of level transitions between a series of data zeros, a series of data ones, and the non-data J-K sequence.

The received signals at 1 MHz, 2 MHz, 4 MHz, and 7 MHz are shown in Figures 11 though 14 respectively. The ripples seen in the 2 MHz and 4 MHz signals of Figures 12 and 13 respectively were produced at the transmitter by the signal generator. Note that in Figure 14 the 7 MHz received signal no longer resembles the input square wave and so provides an

upper signal rate bound. Referring to Figure 15, the design criteria of a transit time of less than 25 ns between the 10% and 90% voltage levels is depicted. This demonstrates the modeled received signal meets the transit time design criteria.

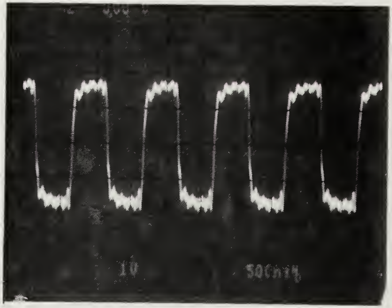


Figure 11. Oscilloscope Display of Received Signal at 1 MHz 3.8 volts and peak-to-peak

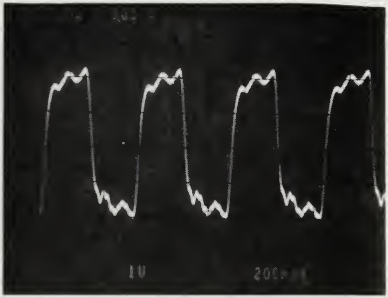


Figure 12. Oscilloscope Display of Received Signal at 2 MHz and 4.2 volts peak-to-peak

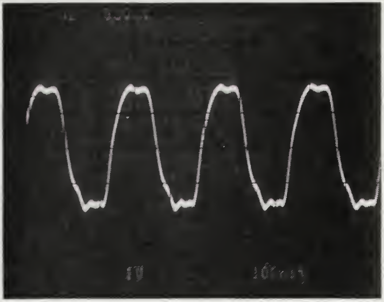


Figure 13. Oscilloscope Display of Received Signal at 4 MHz and 3.8 volts peak-to-peak

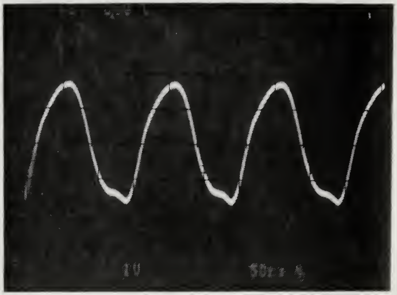


Figure 14. Oscilloscope Display of Received Signal at 7 MHz and 3.8 volts peak-to-peak

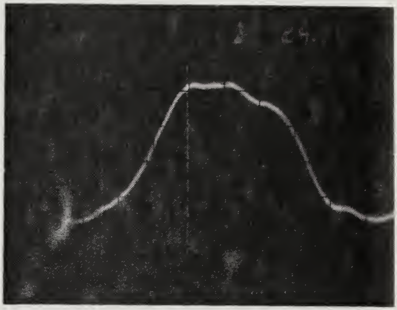


Figure 15. Oscilloscope Display of Received Signal at 4 MHz Showing a 24.30 ns Transit Time Between the 10% and 90% Voltage Levels as marked by the cursors.

To further evaluate the design, a duplicate fiber optic link was constructed for experimental insertion into the LAN. Referring to Figure 16, the input signals to the fiber optic links are the LAN signals from the wiring concentrator; the output signals are fed to the receive pair on the LAN adapter card. Figure 17 shows the input LAN signal to the fiber optic link. Figure 18 shows the corresponding LAN signal at the distant end of the fiber optic link after successful transmission through the link.

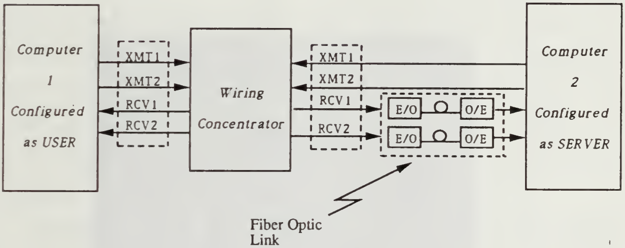


Figure 16. Local Area Network System Block Diagram with Inserted Fiber Optic Link

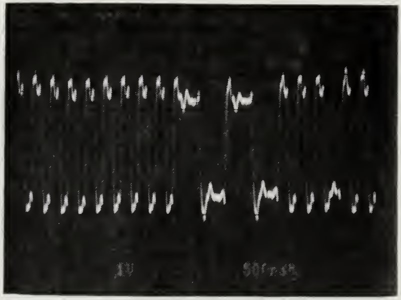


Figure 17. Oscilloscope Display of LAN Signal of the Input to the Transmitter circuit 4 volts peak-to-peak

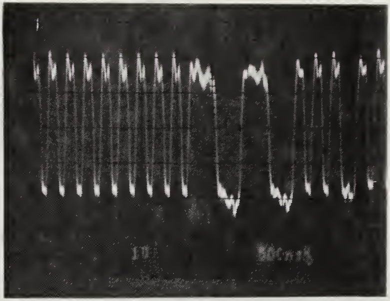


Figure 18. Oscilloscope Display of LAN Signal at the Output of the Receiver Circuit 4.2 volts peak-to-peak

The final evaluation of the design was a question of transparency. A transparent insertion as defined in Chapter I conforms to the following criteria:

- o meet existing standards of Reference 3 developed for dual twisted-pair copper wire,
- o not adversely affect the software protocol, and
- o allow the LAN to communicate over the fiber optic link.

Using the NCR network software, messages were passed from one computer to the other over the design link and were accurately received.

NCR network software allows the direct use of a network computer's hard disk drive by another computer on the network. This feature was also used to evaluate the design link. Using the LAN computer without the fiber optic link (the User), a file was created and saved on hard drive of the LAN computer with the fiber optic link (the Server). This same file was then repeatedly recalled by the user computer, modified, and saved back on the server computer's hard drive with complete accuracy.

Although not exhaustive, the evaluation of this design supplies documentation of all original objectives as stated in Chapter I.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This thesis accomplished the design goal of producing fiber optic link for a token-ring LAN. The ultimate test of this link would be to utilize it in both the transmit and receive signal pairs. This is not possible due to the AC nature of the optical receiver circuit and its inability to pass the DC voltage provided by the phantom drive. (Recall that phantom drive activates the relays of the wiring concentrator to insert the station into the ring.) Within a fiber optic LAN, the insertion is accomplished by control information carried by special MAC frames. [Ref. 1:p. 240]

B. RECOMMENDATIONS

The following list provides follow-on research topics in this area and includes both hardware and software issues.

- Modify/write the software to allow insertion into the ring via MAC frames.
- Replace the wiring concentrator with optical fiber star coupler.
- Multiplex the transmit pair and receive pair to reduce the cable requirement from 4 to 2 optical fibers.

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Thesis
A4585 Anderson
c.1 Design and implementation of a token-ring fiber optic local area network interface module.